
NUCLEAR ENERGY RESEARCH INITIATIVE

Model Based Transient Control and Component Degradation Monitoring in Generation IV Nuclear Power Plants

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A project is proposed to support the development of advanced nuclear power technology and to help position it as a highly competitive and safe method of energy generation. The project will develop a highly advanced and integrated methodology for constructing model-based control systems for Generation IV-based nuclear generating stations. The project will also develop an advanced approach for monitoring nuclear plant systems for system degradations. These two tasks are united by their reliance on smart sensor networks that map sensor signals to plant state information. This plant state information is used to connect models of plant state to the actual plant state. Nonlinear state-space control algorithms based on a Hamiltonian formulation of the control problem can then provide robust and automatic plant control in a wide variety of plant transient maneuvers, such as start-up, shutdown, and load follow maneuvers, including large or total load rejections. By providing smooth transient control without reactor trip these control systems can greatly improve both plant safety and economics. The quest for long-life cores in highly integrated and modular reactor designs places great demands on the already difficult maintenance systems of nuclear power stations. Development is proposed of a systematic statistical methodology for monitoring plant performance degradation. By solving a Master equation

for the probability of finding the plant in a given system state and having a given set of component states, it is possible to determine the probability that the plant is in a given component state, given a set of plant sensor signals. Such advanced degradation monitoring will allow nuclear plant operators to optimize plant maintenance procedures that are subject to both safety and economic factors.

The work proposed will provide the nuclear engineering community with two new capabilities:

- (1) A method to develop robust nonlinear control algorithms that combine plant sensor measurements with a physical model of key plant systems.
- (2) A methodology for plant system degradation monitoring based on comparing plant sensor readings with a physical model of key plant systems.

These methods for fusing sensor data with physical models of plant systems will allow nuclear plant engineers to design optimal maintenance and control strategies at the onset for the new generation of nuclear plants. They will provide nuclear plant operators with tools to operate their plants safely and efficiently within the complex energy market of the 21st century.